

## Structural Evidence for Sensory Function in the Apical Organ of *Macracanthorhynchus hirudinaceus* (Acanthocephala)

T. T. DUNAGAN<sup>1</sup> AND S. SCHMITT<sup>2</sup>

<sup>1</sup> Department of Physiology, Southern Illinois University, Carbondale, Illinois 62901 and

<sup>2</sup> Center for Electron Microscopy, Southern Illinois University, Carbondale, Illinois 62901

**ABSTRACT:** The prominent cone-shaped elevation on the apex of the proboscis of *Macracanthorhynchus hirudinaceus* is the termination for a pair of nerves from the cerebral ganglion as well as a “duct” from the sensory support cell (stützzelle). When the area posterior to the floor of this cone was examined using electron microscopy, a complex branching pattern emerged for the pair of apical sensory nerves. Each branch contained numerous ciliated structures that extended to the pit formed by the cone. Many of these cilia extended through the pit wall into the outside environment. We interpret the presence of cilia in this location as circumstantial evidence that one of the functions of the apical organ is sensory. If this is true, then these branches of the apical sensory nerves are receptors.

**KEY WORDS:** Acanthocephala, apical organ, cilia.

The function of the apical organ in Acanthocephala probably has been discussed since it was first observed. One of the earliest suggested functions was sensory. Schneider (1868) provided a description of the neuroanatomy of *Macracanthorhynchus hirudinaceus*, which included neurons that terminated in the apex of the proboscis. He indicated that these neurons probably were sensory. Leuckart (1876) described an anterior medial nerve that was located between the proboscis retractor muscles and ended at the proboscis tip in a sensory papillae. Kaiser (1893) clearly stated that the anterior medial nerve terminated in a nerve bundle. He believed this to be a sensory papillae but cautioned that the actual function was unknown. Kilian (1932) and Meyer (1933) accepted the position of these investigators as have more recent authors (Hyman, 1951; Dunagan and Miller, 1991). Nevertheless, other authors have suggested that these devices perform a different role. Hamann (1891) thought they were secretory or glandular. Bullock (1965) observed large quantities of glycoaminoglycans and cytoplasmic RNA and noted that the apical organ of *Octospiniferoides chandleri* histochemically had a strong positive aldehyde-fuchsin reaction. He considered these observations as evidence of secretory activity. It is, of course, possible that these apical proboscis structures perform more than a single function.

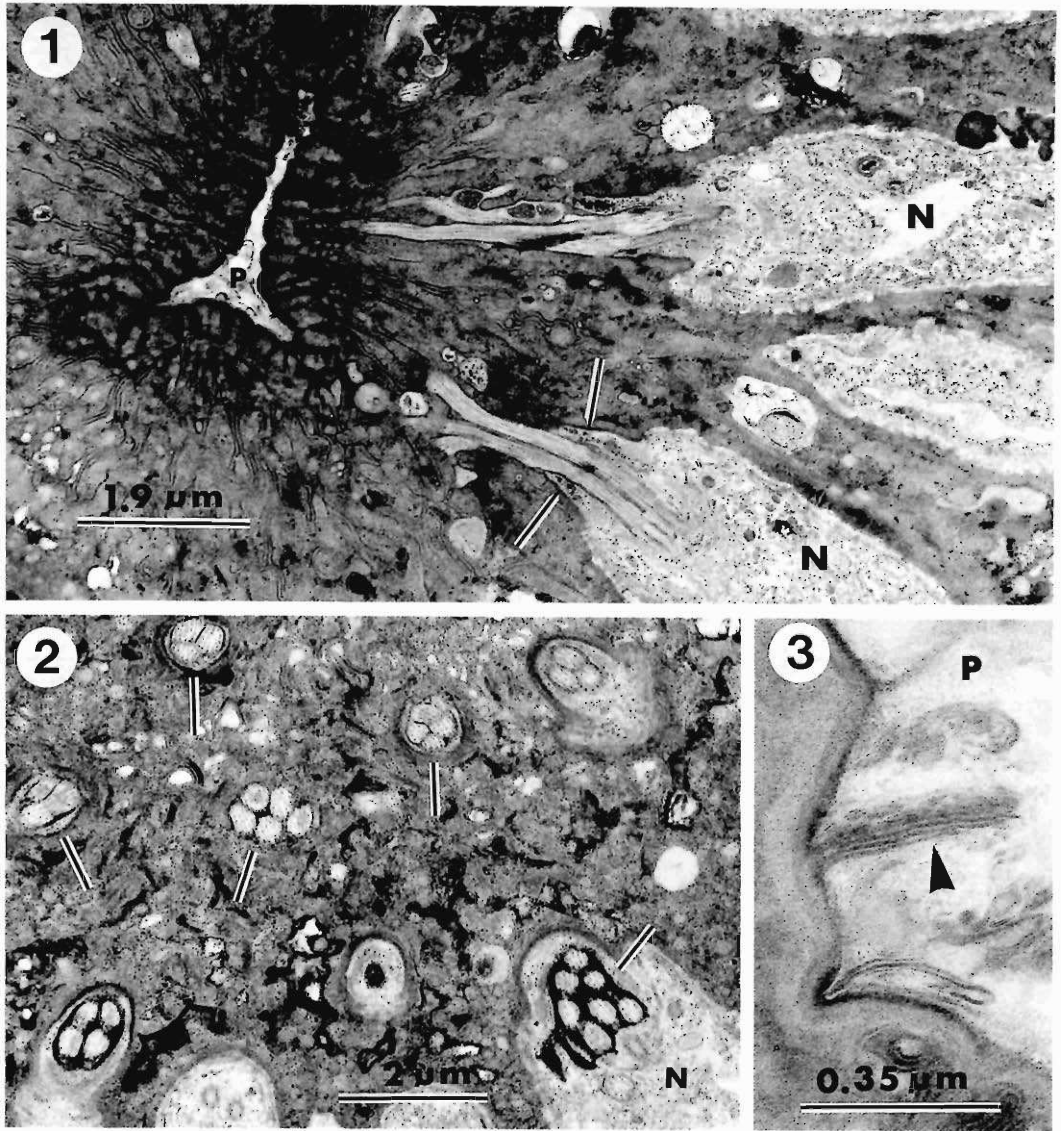
It is the purpose of this paper to describe the presence of ciliated structures in the apical organ of *M. hirudinaceus*. We believe this is circumstantial evidence of a sensory function.

### Materials and Methods

Living *M. hirudinaceus* were collected from pigs through the courtesy of Reelfoot Meat Packaging, Union City, Tennessee. Nodules with attached worms were removed from the small intestine and placed in a Dewar flask containing intestinal contents. Following transport to the laboratory, the acanthocephalans were detached from the intestine, rinsed in 30% sea water, and fixed for 1 hr at room temperature in a mixture of 2% glutaraldehyde and 0.2 mM cacodylate buffer (pH 7.2) containing 2.0 mM EGTA and 1.0 mM MgSO<sub>4</sub>. After fixation, specimens were rinsed in 0.2 M cacodylate buffer and then postfixed for 2 hr at room temperature in freshly prepared 1% OsO<sub>4</sub> and 1.5% K<sub>3</sub>Fe(CN)<sub>6</sub>. Some specimens remained in glutaraldehyde fixative for several weeks. The worms were rinsed in double-distilled water, stained with 1% aqueous uranyl acetate, dehydrated, and then infiltrated and embedded with Spurr's epoxy resin. Sections were cut, and slot grids were prepared and examined in a Hitachi H500H electron microscope. A more detailed outline of the procedures used was reported by Dunagan and Bozzola (1989).

### Results

A cross-section through the posterior portion of the cone-shaped elevation at the apex of the proboscis (Figs. 1, 3, 5) shows an open pit (P) partially filled with “debris.” The fluted margins of the pit are surrounded by radiating groups of microtubules organized in packets of cilia. These packets weave a complicated pattern (Fig. 2) as they progress toward the pit opening. The microtubules in these packets emanate from the terminal portion of branches of sensory nerves (N). As these microtubules exit the nerve, the neurocytoplasm is restricted. This results in the

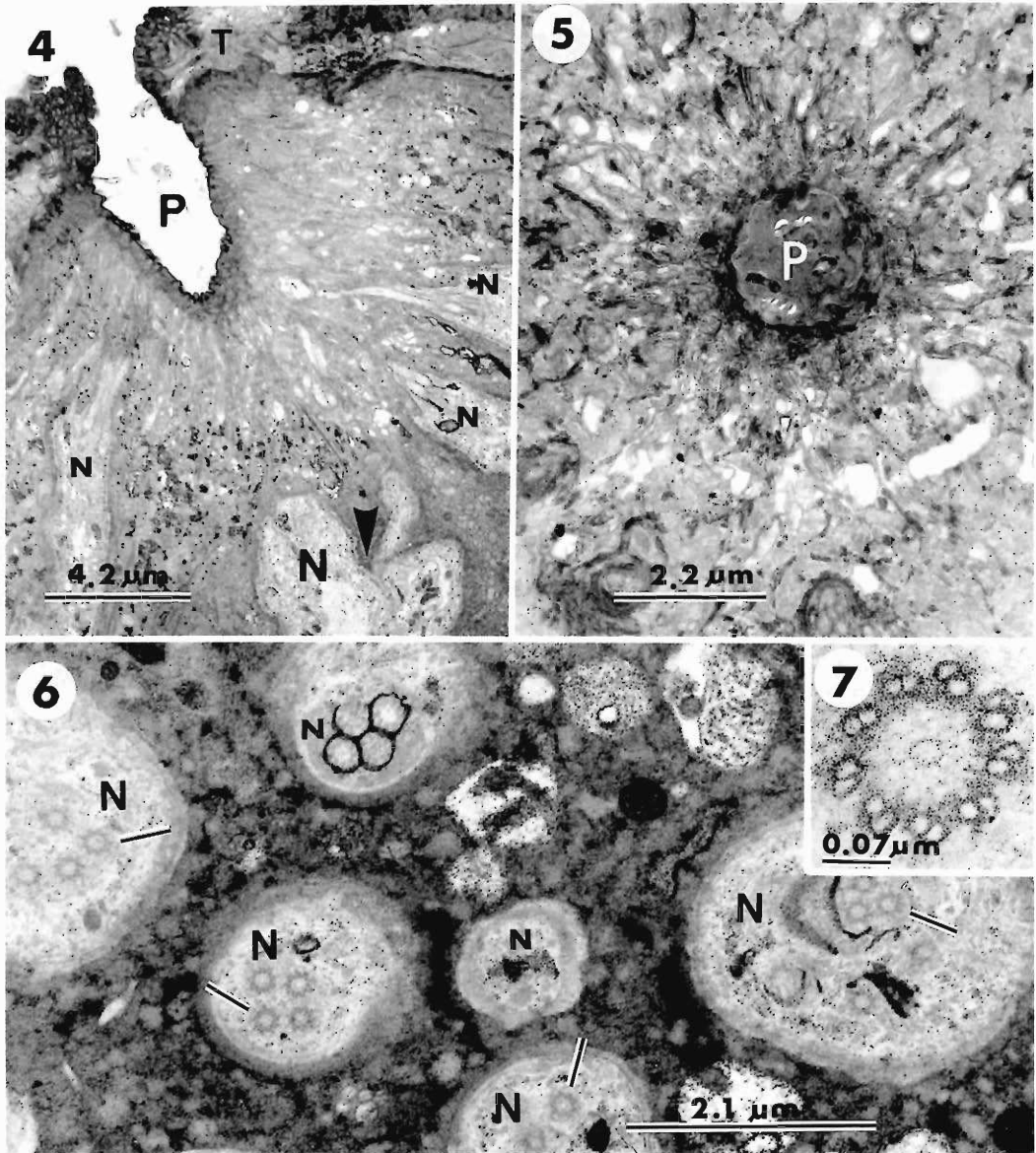


Figures 1–3. Electron micrographs of apical organ of *Macracanthorhynchus hirudinaceus* in vicinity of pit on apex of proboscis. 1. Cross-section showing sensory nerves terminating in cilia that extend to pit. Shafts denote collar formed around cilia as they leave neuron. 2. Tangential section posterior to apical pit. Shafts denote packets of microtubules. 3. Cross-section through pit of apical organ. Note that microtubules extend into pit opening. Abbreviations: N = sensory neuron, P = apical pit.

formation of a collar (Fig. 1; shafts) around the exiting tubules, following which they are outside the nerve for the remaining distance to the pit. Some of these tubules extend into the pit opening, maintaining the same general organization (Fig. 3) here as inside the apical organ. Some of the clefts in the pit wall show no cilia but, instead, appear to open to the inside of the apical organ.

Occasionally, tubelike structures (Fig. 1) can be traced to these clefts, but most sections show them disappearing in the immediate vicinity of the pit wall. Sagittal sections show (Fig. 4) that these nerve extensions enter the floor of the pit as well as its sides, but always posterior to the tegument (T).

Much of the “debris” in the pit (Figs. 1, 3, 5)



Figures 4–7. Electron micrographs of apical organ of *Macracanthorhynchus hirudinaceus* in area of pit on apex of proboscis. 4. Sagittal section showing that tegument forms part of pit wall. Note branch in neuron (arrowhead). 5. Cross-section through pit. Note abundance of microtubules and microfilaments that radiate from pit. 6. Cross-section of neurons below pit floor. Several neurons contain packets of microtubules. 7. Enlarged view of packet shows microtubule pattern of 9+0.

consists of fragmented microtubules and other filamentlike items. However, the pit may be largely empty (Fig. 4) or completely filled (Fig. 5). In either case, its margins never are smooth. Note that the tegument forms the lining of the pit next to its opening (Fig. 4) and that there is

a clear demarkation between the apical organ and tegument.

Detailed examination of nerve cross-sections show numerous groups of microtubules (Fig. 6). The microtubules in Figure 6 are typical of cross-sections of cilia with 9+0 doublets (Fig. 7).

### Discussion

The presoma of *M. hirudinaceus* is crowned with a cone-shaped elevation that resembles a small volcano in appearance. The historical perspective as to function recently has been reviewed (Dunagan and Bozzola, 1989, 1992). These authors have also shown that this apical organ (AO) is served by a pair of nerves from the cerebral ganglion as well as a duct from the sensory support cell (stützelle). The relationship of these 2 entities still is unclear. The apical sensory nerves (SNs) were separated from the anterior proboscis nerves (APNs) (Dunagan and Miller, 1983) when it was recognized that the paired APNs terminated in different areas. The evidence presented in this study indicates that the SNs terminate in the pit wall or the opening of the pit in the cone-shaped elevation. Part of the outermost inside surface of the pit is formed by the AO. Throughout that part of the pit formed by the AO, there are microtubules extending into the "open" area of the pit. Extended time in the fixative tends to remove these structures and is probably the reason more are not visible in the electron micrographs presented here. In addition, the lining of the pit appears to have clefts. These may be openings into the AO or sites of present or former microtubules as they penetrate the pit wall.

The presence of numerous microtubules organized into cilia that penetrate the pit wall of the AO is evidence that one function of the AO is transduction of chemical sensory information. Assuming that the site of transduction is in the cilia, they would detect chemicals in a liquid phase. A recent symposium (Corey and Roper, 1992) included several papers that pointed out the role of cilia in the reception of sensory stimuli in olfaction, photoreceptors, hair cells, etc. It is therefore clear that cilia act in signal transduction. The alternate question is what do these organized microtubules do in the pit of the AO if not serving as sensory devices? We interpret the presence and pattern of microtubules to support the hypothesis that the SN branches in *M. hirudinaceus* are dendrites of 2 receptor neurons, the soma of which lies in the cerebral ganglion.

### Acknowledgments

Financial support was provided by the Department of Physiology, Southern Illinois Uni-

versity, Carbondale, Illinois. Dr. J. J. Bozzola (Director, Center for Electron Microscopy, SIU) provided helpful advice throughout the study.

### Literature Cited

- Bullock, W. L.** 1965. Histochemical observations on the neoechinorhynchid apical organ. *Journal of Parasitology* 51(2, Sect. 2):20.
- Corey, D. P., and S. O. Roper.** 1992. Sensory Transduction. The Rockefeller University Press, New York. 424 pp.
- Dunagan, T. T., and J. J. Bozzola.** 1989. Fine structure of anterior terminus of apical sense organ in *Macracanthorhynchus hirudinaceus* (Acanthocephala). *Journal of Parasitology* 75:297-302.
- , and ———. 1992. Morphology of the apical organ in *Macracanthorhynchus hirudinaceus* (Acanthocephala). *Journal of Parasitology* 78:899-903.
- Dunagan, T. T., and D. M. Miller.** 1983. Apical sense organ of *Macracanthorhynchus hirudinaceus* (Acanthocephala). *Journal of Parasitology* 69:897-902.
- , and ———. 1991. Acanthocephala. Pages 299-332 in F. W. Harrison and E. E. Ruppert, eds. *Microscopic Anatomy of Invertebrates*. Vol. 4. Wiley-Liss, New York.
- Hamann, O.** 1891. Die Nematelminthen. Beiträge zur Kenntniss ihrer Entwicklung, ihres Baues und ihrer Lebensgeschichte. 1. Heft. Monographie der Acanthocephalen (*Echinorhynchen*). Ihre Entwicklung, Histogenie, Anatomie, nebst Beiträgen zur Systematik und Biologie. I Theil, Verlag von Fischer, Jena, 119 pp.
- Hyman, L. H.** 1951. The Invertebrates. Vol. 3: Acanthocephala, Aschelminthes and Entoprocta, the Pseudocoelomate bilateria. McGraw-Hill, New York, Toronto, and London. 572 pp.
- Kaiser, J. E.** 1893. Die Acanthocephalen und ihre Entwicklung. In R. Leuckart and C. Chun, eds. *Bibliotheca Zoologica*. Zweiter Theil, Heft 7. Verlag von Theodor Fischer, Cassel. 148 pp.
- Kilian, R.** 1932. Zur Morphologie und Systematik der Gigantorhynchidae (Acanthoceph.). *Zeitschrift für Wissenschaftliche Zoologie* 141:246-345.
- Leuckart, K. G. F. R.** 1876. Die menschlichen Parasiten und die von ihnen herrührenden Krankheiten. Pages 513-882 in C. F. Winter'sche Verlagshandlung, eds. Ein Hand- und Lehrbuch für Naturforscher und Aerzte. Vol. 2. Leipzig und Heidelberg.
- Meyer, A.** 1933. Acanthocephala. Pages 333-582 in Dr. H. G. Bronn's Klassen und Ordnungen des Tier-Reichs, Band 4, Abt. 2, Lief. 2. Akademische Verlagsgesellschaft, Leipzig.
- Schneider, A. F.** 1868. Ueber den Bau der Acanthocephalen. *Archiv für Anatomie, Physiologie und Wissenschaftliche Medicin* (5):584-597.